

NRMRL HANDOUT FOR MINING

KEY TOPICS:

Arsenic Treatment in Soil, Surface Water and Groundwater:

1.) Activity III, Project 7: **Arsenic Oxidation**

The Arsenic Oxidation Project was proposed to demonstrate and evaluate **arsenic oxidation** and removal technologies. It demonstrated the use of an innovative technology which oxidized arsenite to arsenate in drinking and smelter process water to make the arsenic easier to remove by the BDAT process.

Completed: 6/97 ; Contact: Roger Wilmoth

2.) Activity III, Project 9: **Arsenic Removal**

The purpose of the Arsenic Removal Demonstration Project was to demonstrate three alternative treatment technologies capable of **removing arsenic** from mineral industry effluents to below 50 ppb.

Completed 12/98 ; Contact: Roger Wilmoth

3.) Activity IV, Project 5: **Removal of Arsenic As Storable Stable Precipitates**

The objective of this project was to strip arsenic from solutions in such a way as to produce apatite mineral-like precipitated products that are **stable for long-term storage in tailing pond environments**.

Completed: 5/97 ; Contact: Roger Wilmoth

4.) Ripley, Earle A., Redmann, Robert E., and Crowder, Adele A., **Case Study 3. Deloro and the Moira River**, *Environmental Effects of Mining*, pp.167-170, 1996.

Drainage water from around the site is pumped into settling tanks and treated with ferric chloride to precipitate arsenic as ferric arsenate. The resulting sludge is sufficiently toxic that it must be contained indefinitely in storage lagoons. The treated water, after 99.5% of its arsenic has been removed, is discharged to the Moira River.

Selenium Treatment in Surface Water, Surface Soils:

1.) Activity III, Project 20 – **The Selenium Removal/Treatment Alternatives Demonstration Project**

Will determine the effectiveness of various **selenium removal processes**, including the Best Demonstrated Available Technology, an innovative physical/chemical process, a biological process, and an enzymatic process. The project is being conducted at an operating mineral industry site in Utah.

Date of Completion: 1/01 ; Contact: Alva Daniels

Genetically Resistant Organisms; Biologic Communities Adapted to Naturally Mineralized Conditions:

1.) Activity III, Project 3: Sulfate-reducing Bacteria Demonstration;

Acid generation typically accompanies sulfide-related mining activities and is a widespread problem. Acid is produced chemically, through pyritic mineral oxidation, and biologically, through bacterial metabolism. This project focuses on a **source-control technology** that has the potential to significantly retard or prevent acid generation at affected mining sites. **Biological sulfate reduction** is being demonstrated at an abandoned **remote mine site** where acid production is occurring with associated metal mobility. Bacteria and organic substrate were added to the flooded, underground mine workings to create an in situ biological reactor.

Completion Date: 1/02 ; Contact: Diana Bless

2.) Activity III, Project 13 Hydrostatic Bulkhead with Sulfate-Reducing Bacteria

Will demonstrate a combination hydrostatic bulkhead constructed of concrete and rebar, with a colony of SRBs placed behind the bulkhead. The acid drainage in the mine will be treated by raising the pH of the contained water behind the bulkhead causing metals to be removed. **Metal removal** processes that can occur include adsorption and complexation of metals by organic substrates, biological sulfate reduction, and filtration of suspended and colloidal materials. Biological sulfate reduction, however, should be the predominant metal removal mechanism.

Completion Date: 9/01 ; Contact: Ivars Licis

3.) Activity III, Project 18: Gas-fed Sulfate-reducing Bacteria Berkeley Pit

This project will demonstrate and evaluate a process with the potential to profitably **recover copper, zinc, and sodium hydrosulfide** from Berkeley Pit water. This project was cancelled due to operational problems.

Completion Date: 2/00 ; Contact: Diana Bless

4.) Activity III, Project 12: Sulfate-reducing Bacteria Reactive Wall

By **injecting source control materials** strategically in the surface waste pile, there will be a decrease in waters infiltrating through the pile, thereby, decreasing the environmental impact caused by the pile. This technology will be applied **in situ**, meaning that the pile will be **stabilized in place** and not excavated and moved to another location for stabilization.

Completion Date: 12/00 ; Contact: Alva Daniels

5.) Activity III, Project 14: Biological Barrier

The **microbial capping technology** involves the stimulation of beneficial bacteria at the surface of the tailings or waste-rock pile to remove oxygen from water infiltrating the waste, thereby reducing acidic drainage and stabilizing dissolved metal ions.

Completion Date: 9/00 ; Contact: Ivars Licis

6.) Activity III, Project 24 - **Improvements in Engineered Bioremediation of Acid Mine Drainage**

The objective is to demonstrate **improvements of bioremediation** on acid mine drainage through 1) selection of a better media with organic carbon 2) design of permeability and contact time enhancing system 3) design of an organic carbon replaceable cartridge system 4) development of computer software to simulate SRB bioremediation process in the bioreactor.

Completion Date: 11/04 ; *Contact:* Diana Bless

Wetlands Restoration:

1.) U.S. EPA **SITE *Emerging Technology Summary Handbook for Constructed Wetlands Receiving Acid Mine Drainage***, Office of Research and Development, Cincinnati, Ohio 45268, EPA/540/SR-93/523, September 1993.

U.S. EPA ***Handbook for Constructed Wetlands Receiving Acid Mine Drainage***, EPA/540/93/523.

Pilot test of anaerobic wetlands to treat discharge from the Big Five Tunnel, Idaho Springs, CO

Completed ; Contact: Ed Bates

2.) U.S. EPA ***Engineering Bulletin Constructed Wetlands Treatment***, Office of Research and Development, Cincinnati, Ohio 45268, EPA/540/S-96/501, August 1996.

Completed ; Contact: Ed Bates

3.) Ripley, Earle A., Redmann, Robert E., and Crowder, Adele A., ***Environmental Effects of Mining***, pp.132, 1996.

Wetland should be considered when the treatment of tailings and spoils is being planned, as leaching of added fertilizers or of acid drainage may result in excessive levels in their basins. There is considerable expertise in rehabilitating or creating wetlands with high diversity. This can be done, for example, by creating varied slopes, indented shorelines, and islands that can be used by waterfowl, mammals, and fish.

4.) U.S. EPA, NRMRL, ***Anaerobic Compost Constructed Wetlands System (CWS) Technology DRAFT***, Innovative Technology Evaluation Report, February 1999.

Demonstration of anaerobic wetlands, upflow and downflow cells, to treat discharge from the Burleigh Tunnel, Clear Creek Superfund Site.

Completed ; Contact: Ed Bates

Feasibility/Effectiveness of Closing/Isolating/Reclaiming/Stabilizing Acid Generating Tailings or Waste Piles in Streamside Settings:

1.) Activity III, Project 10: **Surface Waste Piles Source Control**

Demonstrates the feasibility of source control materials, i.e., **innovative grouts**, as surface waste pile stabilization materials. Stabilizing and/or encapsulating the surface waste pile in situ will provide hydrogeologic control by reducing water influx &

minimizing the production of AMD at a nonferrous metal mine.

Completion Date: 09/00 ; *Contact:* Roger Wilmoth

2.) Activity III, Project 12: **Sulfate-reducing Bacteria Reactive Wall**

By **injecting source control materials** strategically in the surface waste pile, there will be a decrease in waters infiltrating through the pile, thereby, decreasing the environmental impact caused by the pile. This technology will be applied **in situ**, meaning that the pile will be **stabilized in place** and not excavated and moved to another location for stabilization.

Completion Date: 09/00 ; *Contact:* Alva Daniels

3.) Activity III, Project 14: **Biological Barrier**

The **microbial capping technology** involves the stimulation of beneficial bacteria at the surface of the tailings or waste-rock pile to remove oxygen from water infiltrating the waste, thereby reducing acidic drainage and stabilizing dissolved metal ions

Completion Date: 09/00 ; *Contact:* Ivars Lics

4.) Activity III , Project 15 **Engineered Tailings Cap**

Demonstrates the ability of a engineered tailings cap that incorporates mine tailings, (remnant mining process material) with a **source control material to stabilize the tailings pile**. The use of an in situ capping technology would reduce wind and water erosion and would be cost effective in most cases.

Completion Date: 09/00 ; *Contact:* Roger Wilmoth

5.)Activity III, Project 19: **Support to SITES Program In-Situ Mercury Removal**

Will conduct comparative mercury stabilization tests using mercury-contaminated material from a waste rock pile. Mercury contamination often is a critical problem at mine sites, and there is a recognized need to identify technologies for mercury remediation. The application of an **in situ mercury stabilization technology** would provide an alternative treatment to complete removal of mercury-contaminated materials from remote abandoned mine sites.

Completion Date: 09/00 ; *Contact:* Ed Bates

6.) **Mercury stabilization**

ORD/NRMRL is working with Region 9,the SITE program, and vendors to develop/test methods for in-situ stabilization of Hg in mining waste

Contact: Ed Bates

7.) **Mixed Waste Stabilization/Solidification Demonstration Project.**

This ongoing project is evaluating **4 solidification technologies and protocols** for assessing the leaching of **radionuclides** and long term durability. Lab bench tests have been completed with cement, phosphate, polymer, and vinyl ester styrene.

Completion Date: Draft in Peer Review ; *Contact:* Tri Hoang

8.) **In-situ Stabilization of Waste Rock in Vadose Zone**

ORD/NRMRL is working with Region 8, South Dakota and NRMRL to demonstrate in-situ stabilization of waste rock piles with silicates, phosphates, and permanganate (Vendors - KEECO, STC, SVENSON, RMC, and Univ. of Nevada at Reno). In-situ treatment of lagoons (Sheppard Miller Lime/Microbe Process). In-situ treatment of mine waste below the vadose zone. Contaminants of Concern - Cu, Zn, Se
Completion Date: Spring 2001 ; *Contact:* Ed Bates

Effectiveness of Plugging Mine Adits that Discharge Acid Mine Drainage to Streams (which may be considered the most practical remedy in remote areas)

1.) Activity III, Project 2: **Clay-based Grouting Demonstration**

Surface and groundwater inflow into underground mine workings becomes a significant environmental problem when water contacts sulfide ores, forming acid drainage. **Clay-based grouting**, the technology selected for this demonstration, has the ability to reduce or eliminate water inflow into mine workings by establishing an impervious clay curtain in the formation.

*Completed:*04/97 ; *Contact:* Roger Wilmoth

2.)Activity III, Project 8: **Underground Mine Source Control**

By injecting a **source control material**, underground pathways (fractures) will be sealed, and an impervious groundwater barrier will be formed. Materials testing will be performed to determine which source control material will be selected. Demonstrates the feasibility of a **grout material (Hydro Active Combi Grout)** for reducing water influx and minimizing the production of acid mine drainage at a nonferrous metal mine

*Completion Date:*11/04 ; *Contact:* Roger Wilmoth

Improved or New Methods or Technologies for Storage/Remediation of Mine Wastes, Including Engineered Wetlands and Permeable Reactive Barriers:

1.) Activity III, Project 21 - **Integrated Process for Treatment of Berkley-Pit Water**
Applies systems engineering techniques to (1) **optimize costs** for acid rock drainage treatment, and (2) attempt to **improve overall economics** by selective product recovery from the water.

Completion Date: 11/00 ; *Contact:* Diana Bless

2.) Activity III, Project 24 - **Improvements in Engineered Bioremediation of Acid Mine Drainage**

The objective is to demonstrate **improvements of bioremediation** on acid mine drainage through 1)selection of a better media with organic carbon 2) design of permeability and contact time enhancing system 3) design of an organic carbon replaceable cartridge system 4) development of computer software to simulate SRB bioremedial process in the bioreactor.

Completion Date: 11/04 ; *Contact:* Diana Bless

3.) Activity IV, Project 2: **Sludge Stabilization**

The purpose of this research project was to study the properties and stability of sludges generated by remediation of acid mine waters. Results of the study were used to determine the best methods for **sludge handling and disposal**.

Contact: Roger Wilmoth

4.) Activity IV, Project 5: **Removal of Arsenic As Storable Stable Precipitates**

The objective of this project was to strip arsenic from solutions in such a way as to produce apatite mineral-like precipitated products that are **stable for long-term storage in tailing pond environments**.

Completed: 5/97 ; *Contact:* Roger Wilmoth

5.) Activity IV, Project 8: **Pit Lake System**

Characterization and Remediation for the Berkeley Pit several aspects of the Berkeley Pit Lake system were studied to **better understand the system as a whole**, which may **lead to new or improved remediation technologies** to be used during future cleanup. The following research is being conducted on the Berkeley Pit Lake: Biological Survey of Berkeley Pit Water; Sediment/Pore Water Characterization; Sulfate Reducing Bacteria; Surface Oxidation Reactions; Organic Carbon; and Sedimentation Rates.

Completed: 11/99 ; *Contact:* Roger Wilmoth

6.) Activity IV, Project 14: **Artificial Neural Networks as an Analysis Tool for Geochemical Data**

This research applies to **artificial neural network** (ANN) analysis to geochemical and similar data sets; such as those acquired from the Berkeley Pit, Butte, MT.

Completed: 2/00.

7.) **Fry Canyon Field Demonstration Project**

This is an ongoing demonstration of a **Permeable Reactive Barrier wall** to control aqueous concentrations of Uranium in ground water at an abandoned mill tailings site in Utah. Three different materials have been installed (phosphate, zero valent iron, and amorphous iron hydroxide).

Completion Date: Ongoing/2000 ; *Contact:* Ed Feltcom

8.) **Permeable Reactive Barriers for Inorganic Contaminants and Treatment of Acid Rock Drainage**

A permeable zone creating a reactive treatment area oriented to intercept and remediate a contaminant plume. Task 1061 Inhouse Project - Elizabeth City Full-Scale PRB for Cr and TCE. WA SF - 1- 4- PRB for Nitrate and Arsenic contaminated ground water. Task 5851 Inhouse Project - PRB strategies and performance monitoring for remediation of inorganic contaminants.

Contact: Robert W. Puls

Natural Attenuation of Inorganics:

1.) **Natural Attenuation - French Creek site, Breckin Ridge, CO.**

ORD/NRMRL is working with Region 8 to evaluate apparent **natural attenuation of**

some metals in near neutral discharges as such discharges flow through alluvium on the French Creek site, Breckin Ridge, CO. Source of zinc is underground mine discharges through fractures below stream alluvium. Technologies include - lime treatment lagoon, constructed anaerobic wetlands, creation of an alkaline plume in alluvium to cause precipitation of zinc.

Completion Date: Fall 2000 ; *Contact:* Ed Bates

2.) Natural Attenuation - Zortman/Landusky Mine

ORD/NRMRL is working with Region 8 to evaluate apparent **natural attenuation of some metals** by evaluating a passive - semi passive treatment approach to replace existing pump-backs and active treatment plants. ARD sources include deep mines, mine waste rock, heap leach pads - approx. 8 source areas. Technologies - lime treatment lagoons, anaerobic wetlands, aerobic wetlands. Contaminants of concern - Zn, Cu, Mn, Al, Se, Nitrates.

3.) Monitored Natural Attenuation of Inorganics

OSWER recognizes need for monitored natural attenuation of inorganics in ground water and soils. Aberjona watershed in Woburn, MA (industrial site); pesticide manufacturer and tannery. Project reports include - EPA Report on the Natural Attenuation of Arsenic in Soils and Sediments (12/2001). Peer-reviewed journal articles - Preservation methods for maintaining aqueous arsenic speciation in ground water samples (12/2000); Solid phase arsenic speciation as a function of geochemical parameters in soils and sediments (05/2001); Assessing natural attenuation of arsenic in soils and sediments (10/2001).

Contact: Robert W. Puls

Other In-House Research on Natural Attenuation of Inorganics

Task 6400 (Robert Ford): Attenuation/Stabilization of Arsenic by Iron (Hydr)oxides in Soils/Sediments Laboratory Study

Task 4279 (Cynthia Paul): Natural Attenuation of Inorganic Contaminants Laboratory Study, solid phase extraction methods.

Task 7060 (Richard Wilkin): Natural Attenuation of Metals During Sulfide Formation.

Task 6403 (Richard Wilkin): Monitoring Oxidation-Reduction Processes in Ground Water, Sediments.

Task 1579 (Guy Sewell): Microbial Ecology of the Subsurface/Biomarker Development

Treatment or Source Control for Acid or Metals-rich Drainage from Small Mines in Remote Regions:

1.) Activity III, Project 1: EPA asked MSE to develop a treatment facility at one of these sites to treat acidic metal-laden water. Due to the remote nature of these locations, this facility was required to operate for extended periods of time on water power alone, without operator assistance. Year round treatment of AMD coming from the adit of a remotely located metals mine with a chemical precipitation process.

Completed: 6/97 ; *Contact:* Roger Wilmoth

2.)Activity III, Project 3: **Sulfate-reducing Bacteria Demonstration;**

Acid generation typically accompanies sulfide-related mining activities and is a widespread problem. Acid is produced chemically, through pyritic mineral oxidation, and biologically, through bacterial metabolism. This project focuses on a **source-control technology** that has the potential to significantly retard or prevent acid generation at affected mining sites. **Biological sulfate reduction** is being demonstrated at an abandoned **remote mine site** where acid production is occurring with associated metal mobility. Bacteria and organic substrate were added to the flooded, underground mine workings to create an in situ biological reactor.

Completion Date: 01/02 ; *Contact:* Diana Bless

3.) Activity IV, Project 15: **Remote Imaging Spectroscopy-Imaging Spectroscopy**

Is becoming an important **remote sensing** tool for the exploration and analysis of natural resources and environmental hazards. With regards to the Butte-Silver Bow and Clark Fork Superfund Sites, it may prove to be an invaluable asset in the **long term monitoring** and assessment of remediation efforts.

Completion Date: 09/00 ; *Contact:* Roger Wilmoth

Slurry Wall/ Leachate Collection and Treatment Research:

Heavy Metals Water/Wastewater Treatment:

1.) Activity III Project 4: Comparison of three technologies for the **removal of nitrate** from mine water.

Completed: 04/97 ; *Contact:* Roger Wilmoth

2.) Activity III, Project 6: **Pollutant Magnet**

The small-scale pilot project demonstrated a two-step process for **removing arsenic** from contaminated mine water.

*Completion Date:*CANCELLED ; *Contact:* Roger Wilmoth

3.) Activity III, Project 7: **Arsenic Oxidation**

The Arsenic Oxidation Project was proposed to demonstrate and evaluate **arsenic oxidation** and removal technologies. It demonstrated the use of an innovative technology which oxidized arsenite to arsenate in drinking and smelter process water to make the arsenic easier to remove by the BDAT process.

Completed: 06/97 ; *Contact:* Roger Wilmoth

4.)Activity III, Project 9: **Arsenic Removal**

The purpose of the Arsenic Removal Demonstration Project was to demonstrate three alternative treatment technologies capable of **removing arsenic** from mineral industry effluents to below 50 ppb.

Completed: 12/98 ; *Contact:* Roger Wilmoth

5.) Activity III, Project 13: **Hydrostatic Bulkhead with Sulfate-Reducing Bacteria**

Will demonstrate a combination hydrostatic bulkhead constructed of concrete and rebar,

with a colony of SRBs placed behind the bulkhead. The acid drainage in the mine will be treated by raising the pH of the contained water behind the bulkhead causing metals to be removed. **Metal removal** processes that can occur include adsorption and complexation of metals by organic substrates, biological sulfate reduction, and filtration of suspended and colloidal materials. Biological sulfate reduction, however, should be the predominant metal removal mechanism.

Completion Date: 09/01 ; *Contact:* Ivars Lics

6.) Activity III, Project 16: **Integrated Passive Biological Treatment Process:**

This will demonstrate an integrated, passive biological technology to completely treat acid mine drainage emanating from a remote, abandoned, precious-metal mine. The technology will utilize both anaerobic (namely sulfate-reducing bacteria) and aerobic bacteria for complete **removal of all metal contaminants**.

Completion Date: 01/03 ; *Contact:* Diana Bless

7.) Activity III, Project 18: **Gas-fed Sulfate-reducing Bacteria Berkeley Pit**

This project will demonstrate and evaluate a process with the potential to profitably **recover copper, zinc, and sodium hydrosulfide** from Berkeley Pit water.

Completed: 02/00 ; *Contact:* Diana Bless

8.) Activity III, Project 20 – **The Selenium Removal/Treatment Alternatives Demonstration Project**

Will determine the effectiveness of various **selenium removal processes**, including the Best Demonstrated Available Technology, an innovative physical/chemical process, a biological process, and an enzymatic process. The project is being conducted at an operating mineral industry site in Utah.

Completion Date: 01/01 ; *Contact:* Alva Daniels

9.) Activity IV, Project 4: **Metal Ion Removal From Acid Mine Waste Water by Neutral Chelating Polymers**

A bench-scale research project was performed to test a novel technology based on neutral chelating polymers that can have their chelating property turned on and off. The chelate switch was based on known electrochemical or photochemical properties of electrically conducting polymers.

Completed: 04/97 ; *Contact:* Roger Wilmoth

10.) Activity IV, Project 12: **An Investigation to Develop a Technology for Removing Thallium from Mine Waste Waters**

This research will be conducted in response to the need for bench scale laboratory investigations to develop appropriate **thallium removal** technologies.

Two technologies that may be able to meet the proposed thallium level are proposed for laboratory bench-scale experimental study, e.g., manganese dioxide adsorption and reductive cementation of thallium utilizing elemental iron.

Completed: 01/01 ; *Contact:* Roger Wilmoth

11.) Sacramento Sanitation District one million dollar study to develop a Sacramento River Toxic Pollutant Control Program that has **mercury** as one of its principle concerns.
Contact: John Hillenbrand

12.) **Acid Mine Drainage treatment**

ORD/NRMRL is working with Region 8, state of Colorado, and the SITE program to test a “SAPP” system (USBM/DOE Technology), a lime lagoon system (AQUAFIX), and zeolites (Reynolds Engineering) at the Summitville site.

Completion Date: Summer 2000 ; *Contact:* Ed Bates

13.) **Acid Mine Drainage treatment**

ORD/NRMRL is working with Region 8, state of Colorado, and the SITE program to demonstrate a pilot scale test of the BASX Ceramic Filter System to treat acid mine drainage (Cu, Al, Zn, Mn).

Completed ; Contact: Ed Bates

The Superfund Innovative Technology Evaluation Program “Technology Profiles Tenth Edition” Volumes 1, 2, and 3 have a lot of information on Heavy Metal Remediation for Soils, Groundwater, Wastewater, Sediments, Liquids, etc. The reference is EPA, SITE Program, EPA/540/R-99/500a, February 1999.

Cyanide Treatment in Water/Soil/Air:

1.) Activity III, Project 5: **Biocyanide Demonstration**

The main goal of this project was to use a strain of bacteria to destroy **cyanide** associated with precious metal mining operations. Another project goal was to develop a reactor design that will best use the cyanide-degrading effects of the bacteria to destroy cyanide from mining wastewater

Completed: 9/97 ; *Contact:* Roger Wilmoth

2.) Activity III, Project 11: **Cyanide Heap Biological Detoxification**

The basic process for **bio-detoxification of cyanide heaps** has already been identified, demonstrated, and proven to be commercially applicable and effective. However, numerous questions remain about the final efficiency, total capital and operating costs, applicability to multiple ore types, time required to completion, and the effects of the biological treatment on related discharge parameters such as pH, sulfates, nitrates, and entire suites of metals, including recoverable spike concentrations of gold. This project demonstrated the use of four biological process, water rinsing and peroxide rinsing as source control treatments for **cyanide removal** from a gold heap leach operation.

Completed: 02/00 ; *Contact:* Pat Clark

3.) Activity IV, Project 3: **Photoassisted Electron Transfer Reactions Research–**

This research attempted to identify and enhance naturally occurring processes that would help remediate toxic anions while minimizing treatment by-products. In this regard, the use of dissolved and solid photocatalysts was investigated for the **removal of cyanide** and nitrate anions from mine waste waters.

Completed: 04/97 ; *Contact:* Roger Wilmoth

4.)Activity IV, Project 3A: **Photoassisted Electron Transfer Reactions for Metal-Complexed Cyanide**

This research assessed the effects of direct photolysis and homogeneous photolysis for **destruction of cyanide** and cyanide metal complexes.

Completed: 07/97 ; Contact: Roger Wilmoth

5.)Activity IV, Project 3B: **Photoassisted Electron Transfer Reactions for Berkeley Pit Water**

This research examined processes to remediate anions, particularly sulfur as sulfate, arsenic as arsenite and arsenate, nitrate, **cyanide and metal-complexed cyanides**.

Completed: 10/97 ; Contact: Roger Wilmoth

6.)Technical Report: **Treatment of Cyanide Heap Leaches and Tailings**

Completed: 09/94 ; Contact: Roger Wilmoth